Description of Analytical Tools

Name: Consumptive Use Program (CUP)

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Availability of Technical Support: A summary of CUP documentation is available on DWR web site:
(http://www.landwateruse.water.ca.gov/basicdata/agwateruse/cropmodels.cfm)

Categories: Estimation of Daily Crop Coefficients and Crop evapotranspiration

Main Features and Capabilities:

1 Daily time step calculations.
2 Allows input of weather, temperature, ET_o and pan evaporation data for estimating crop evapotranspiration. Weather variables include solar radiation, maximum and minimum temperature, wind speed, dew point temperature, and rainfall.
3 Derivation of daily weather and ET_o data from monthly mean values for one year.
4 Calculations of daily ET_o from daily Penman-Monteith equation.
5 May be used to fill in missing data points where only monthly mean weather and ET_o data exist.
6 Employs the latest methodology to determine crop coefficients for a wide variety of crops.
7 Daily calculations of crop coefficients and crop evapotranspiration for currently entered weather and crop information.
8 Adjusts crop coefficients for wetting frequency from rainfall or irrigation during the off season.
9 Accounts for cover crop and immaturity effects on crop coefficients for tree and vine crops.
10 Outputs one year of daily weather and ET_o data for the current weather information.
11 Outputs one year of daily calculated crop coefficients and ET_c data by crop.
12 Provides monthly mean of daily crop coefficient values by crop during the growing season and off-season.
13 Provides monthly total values of ET_o, ET_c, and rainfall during the growing season and off-season.
14 Seasonal total values of ET_o and ET_c for currently entered crop information.
15 Plots daily calculated reference evapotranspiration during the growing season with different colored lines for each growth period.

16 Plots daily calculated crop coefficients during the growing season with different colored lines for each growth period for the current crop information.
17 Provides a bar graph of monthly total values of ET_o and ET_c during the growing season for the entered crop information.
18 After the data entry, the calculated K_c, ET_o, and ET_c can be written as a row of data in the summary worksheets of K_c, ET_o, and ET_c.
19 Contains monthly values of ET_o, K_c, ET_c, and rainfall during the in-season and off- season.
20 CUP is written with Excel software and runs on IBM PC compatible-equivalent or higher, 16MB RAM, Windows 95/98, NT 4.0, Windows 2000, Windows XP. It is available on CD.

Applications: The model so far has been applied to Davis, Port Hueneme, and Bishop to determine how it performs at sites influenced by coastal and windy desert climates.

Calibration/Validation/Sensitivity Analysis: The Hargreaves-Samani (H-S) equation used by CUP must be calibrated for sites influenced by coastal and windy desert climates; otherwise it may over- or under-estimate ET_o values for a region of interest. The equation does not account for wind speed and requires only the latitude of the site of interest and measurement of the minimum and maximum temperatures for estimating ETo. Nine years of estimated daily ET_o data (1990–1998) from CIMIS (California Irrigation Management Information System) at Davis, Calif., were used to validate our model predictions of ET_o. Figure 1 compares daily mean ET_o estimates of CUP and CIMIS and SIMETAW averaged over the period of the data set at Davis, Calif.. The performance of the CUP was further evaluated at a humid location (Port Hueneme) and windy desert site (Bishop). As seen in figures 1, 2, and 3, a close agreement between CIMIS-based estimates of ET_o and those of the CUP model exists. Monthly mean values of measured weather data averaged over the period of the data set (1990–1998) from CIMIS in Davis were also used in the model to derive one year of daily weather data. The weather data consist of R_s, T_{max}, T_{min}, wind speed, T_{dew}, and rainfall. The weather data derived by CUP were compared with the measured and simulated data from CIMIS and SIMETAW, respectively. Results in figures 4, 5, and 6 showed that R_s, T_{max}, and rainfall values predicted from CUP were well correlated with those values obtained from CIMIS and SIMETAW. The performance of the CUP was further evaluated at a humid location and windy desert site. In all locations, CUP correlated very well with CIMIS and SIMETAW. Similar results were also observed for T_{min}, wind speed, and T_{dew} data in other locations. Sensitivity analysis has not yet been performed in CUP, but we can increase or decrease solar radiation by a factor or change temperature data to see what would happen to the ET_o data.

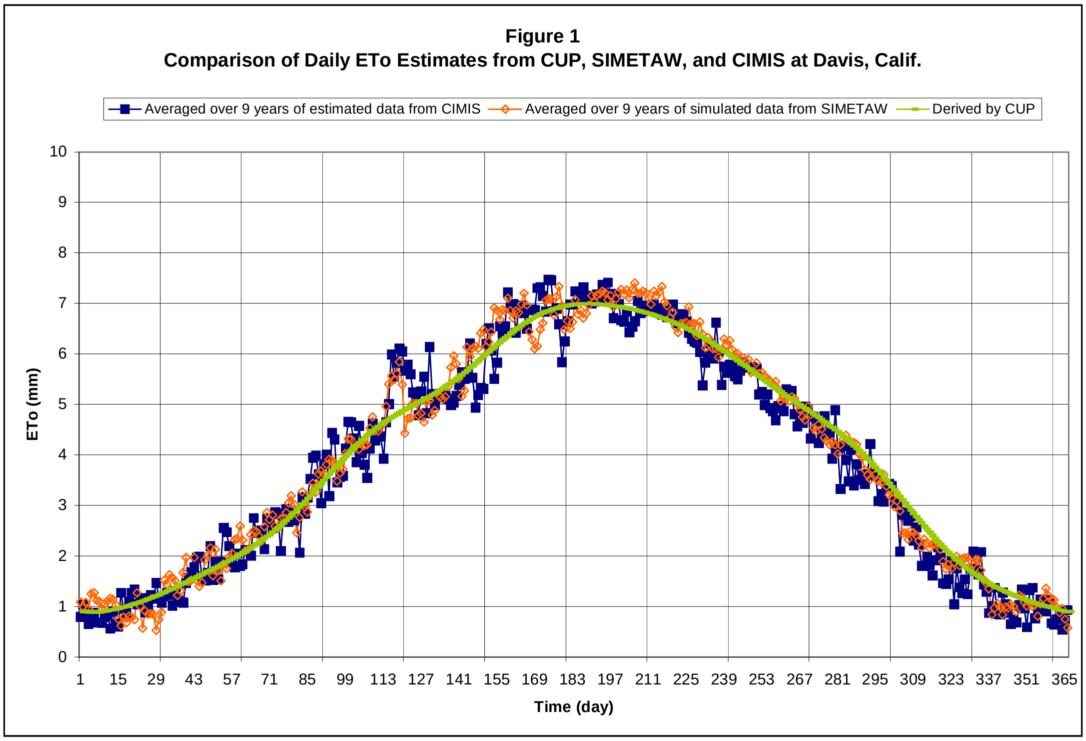


Figure 1
Comparison of Daily ETo Estimates from CUP, SIMETAW, and CIMIS at Davis, Calif.
Averaged over 9 years of estimated data from CIMIS
Averaged over 9 years of simulated data from SIMETAW
Derived by CUP
ETo (mm)
0
1
2
3
4
5
6
7
8
9
10
1 15 29 43 57 71 85 99 113 127 141 155 169 183 197 211 225 239 253 267 281 295 309 323 337 351 365
Time (day)

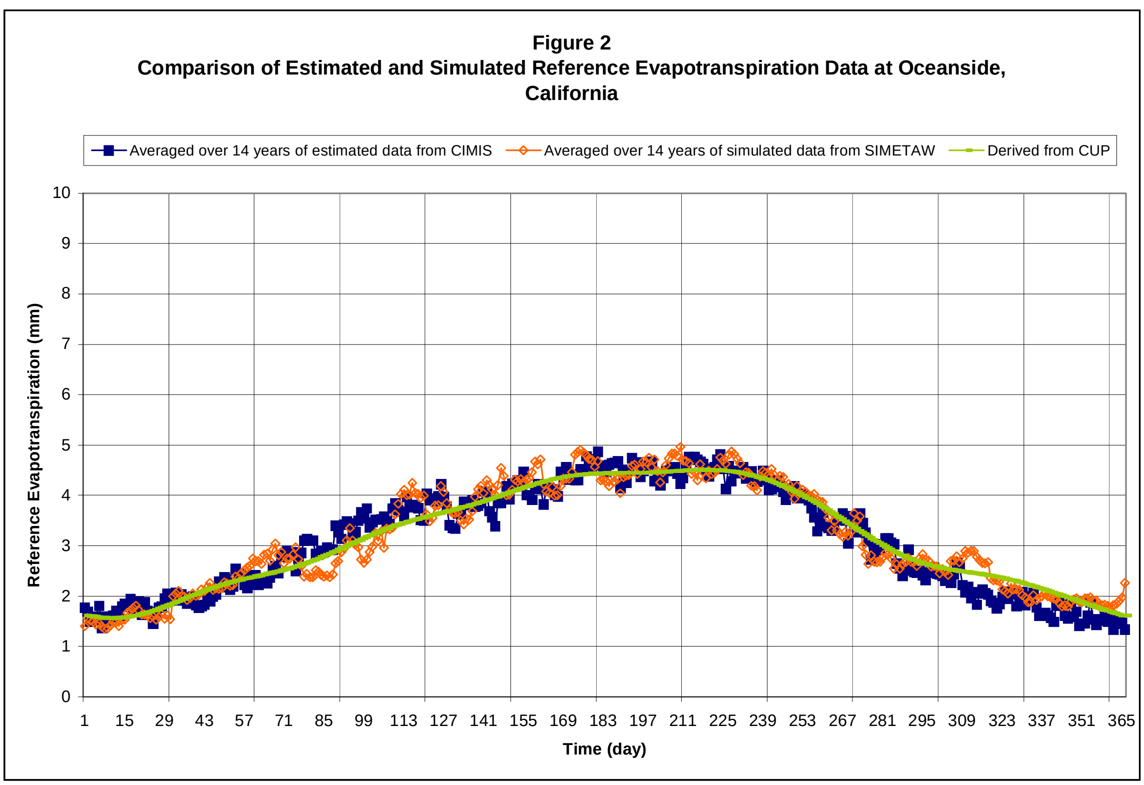


Figure 2
Comparison of Estimated and Simulated Reference Evapotranspiration Data at Oceanside, California
Averaged over 14 years of estimated data from CIMIS
Averaged over 14 years of simulated data from SIMETAW
Derived from CUP
Reference Evapotranspiration (mm)
0
1
2
3
4
5
6
7
8
9
10
1 15 29 43 57 71 85 99 113 127 141 155 169 183 197 211 225 239 253 267 281 295 309 323 337 351 365
Time (day)

Figure 3
Comparison of Daily ETo Estimates from CUP, SIMETAW, and CIMIS at Bishop, Calif.

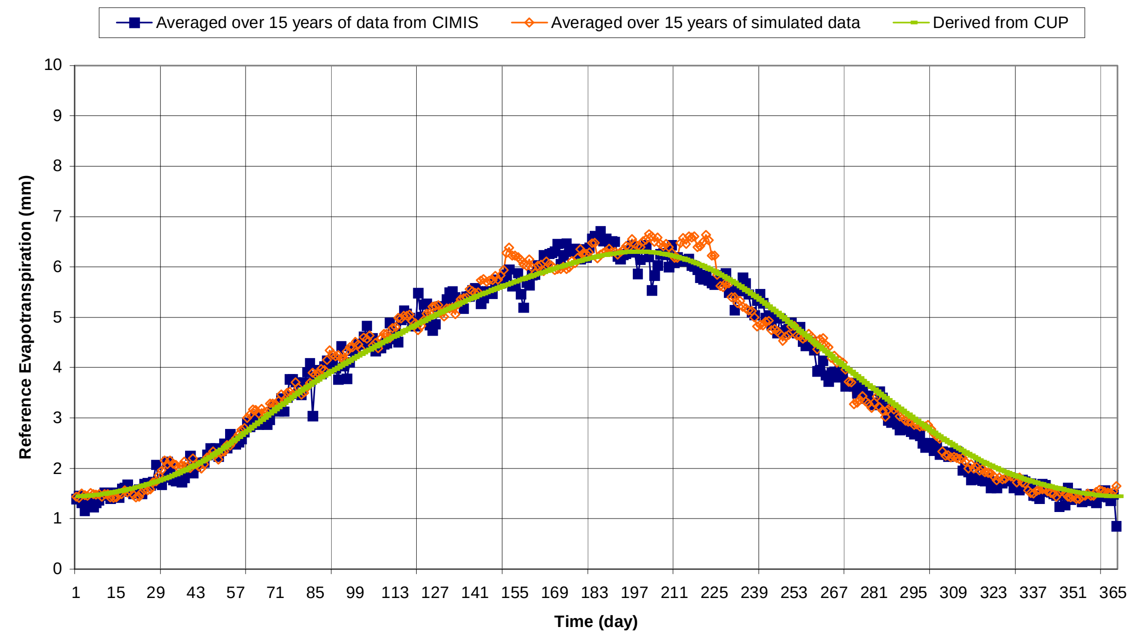
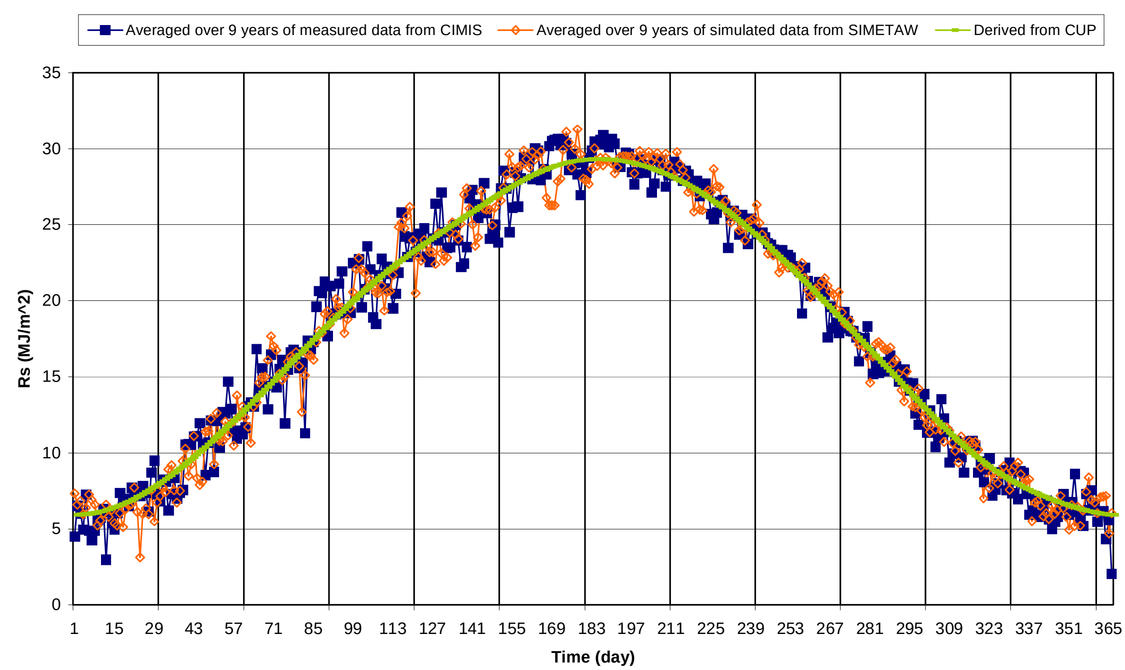


Figure 4
Comparison of Measured and Predicted Daily Solar Radiation Data at Davis, Calif.



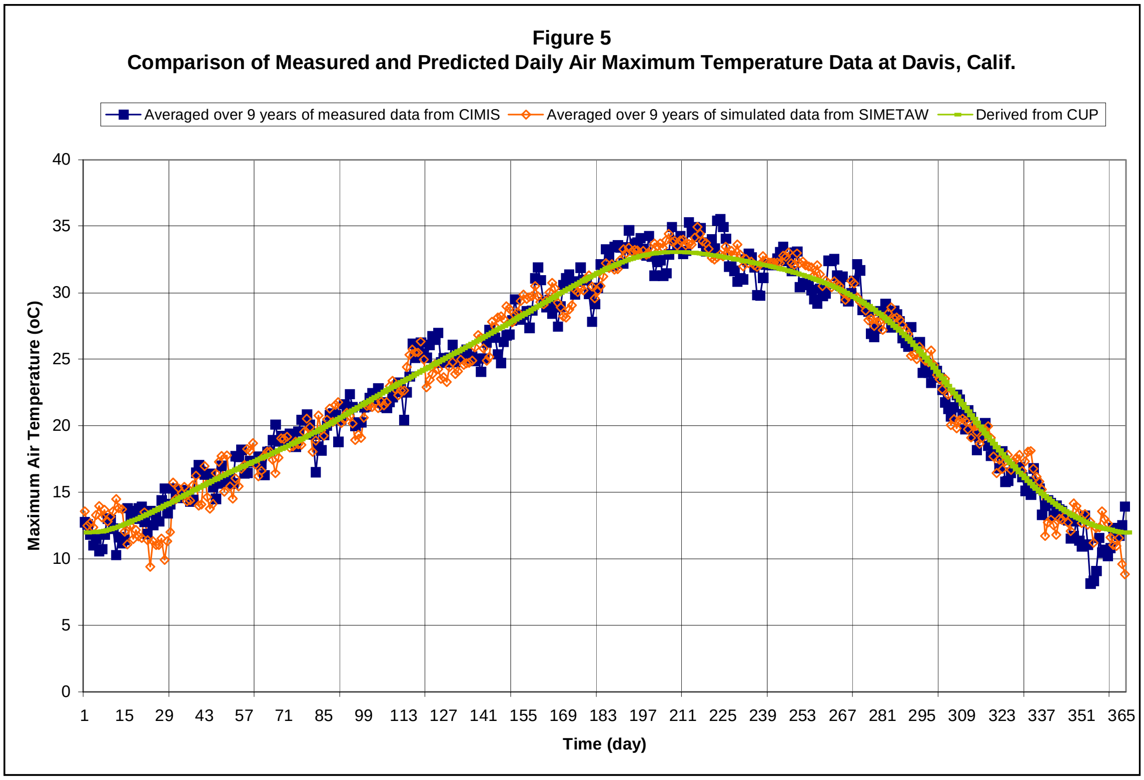


Figure 5
Comparison of Measured and Predicted Daily Air Maximum Temperature Data at Davis, Calif.

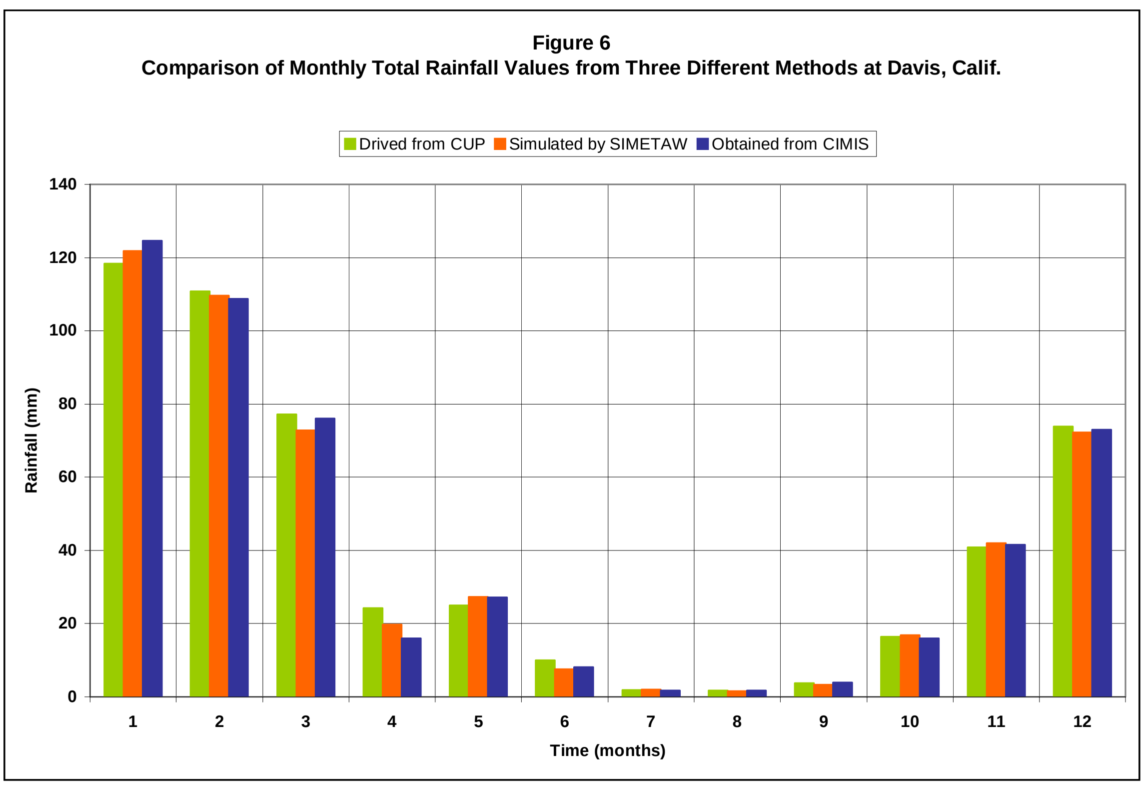


Figure 6
Comparison of Monthly Total Rainfall Values from Three Different Methods at Davis, Calif.

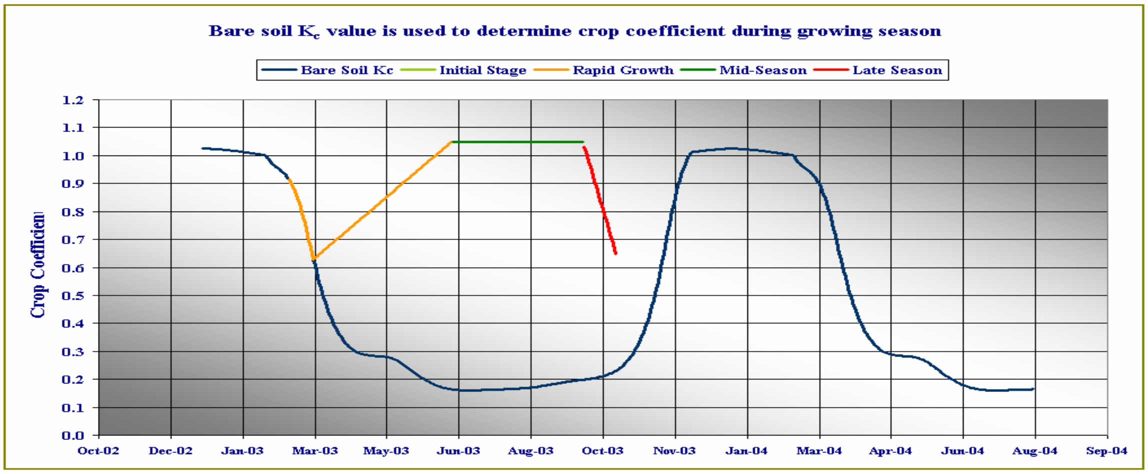
Peer Review: No formal peer review yet.

Anatomy of CUP:

-Conceptual Basis: The primary objective of CUP is to use a curve fitting technique to derive one year of daily weather and ET_o data from 12 monthly mean values and estimates daily crop evapotranspiration (ET_c), where ET_c is estimated by multiplying reference evapotranspiration by a crop coefficient value. All ET_c calculations are done on a daily basis, so the estimation of ET_c is greatly improved over earlier methods. In addition, the use of the widely adopted daily Penman-Monteith equation for reference evapotranspiration (ET_o) and improved methodology to apply crop coefficients for estimating crop evapotranspiration is used to improve ET_c accuracy.

-Theoretical Basis: The theoretical basis of CUP is to improve the dissemination of K_c and crop evapotranspiration (ET_c) information to California growers and water purveyors. CUP computes reference evapotranspiration (ET_o) from monthly means of solar radiation, maximum and minimum temperature, dew point temperature, and wind speed using the daily Penman-Monteith equation. The program uses a curve fitting technique to derive one year of daily weather and ET_o data from the monthly data. In addition, daily rainfall data are used to estimate bare soil evaporation as a function of mean of ET_o and wetting frequency in days. A bare soil K_c value is calculated to estimate the off-season evapotranspiration and as a baseline for in-season K_c calculations. During early growth of crops, when considerable soil is exposed to solar radiation, ET_c is dominated by soil evaporation and the rate depends on whether or not the soil surface is wet. CUP accounts for the influence of orchard cover crops on K_c values and for immaturity effects on K_c values for tree and vine crops. Further, the program computes and applies all ET_o and K_c values on a daily basis to determine crop water requirements by day, by month, by season, and by year.

-Numerical Basis: CUP computes reference evapotranspiration (ET_o) from monthly means of solar radiation, maximum and minimum temperature, dew point temperature, and wind speed using the daily Penman-Monteith equation. Monthly data can come from CIMIS or from a non-CIMIS data source as long as data are in the correct format. In addition, the program uses a curve fitting technique to derive one year of daily weather and ET_o data from the monthly data. Then crop information is used to calculate daily crop coefficients and crop evapotranspiration, for crops. Daily rainfall data are also used to estimate bare soil evaporation as a function of mean of ET_o and wetting frequency in days. During the off-season and during initial crop growth, soil evaporation (E) is the main component of ET. Therefore, a two-stage soil evaporation model is used in CUP to estimate bare-soil crop coefficients as a function of mean ET_o and wetting frequency in days. Then, estimated bare soil coefficient values are used as a base line to adjust crop coefficient values for wetting frequency from rainfall or irrigation during the initial growth period. Figure below shows basic concept of crop coefficient adjustment for wetting frequency from rainfall in CUP.



CUP accounts for immaturity effects on crop coefficients for tree and vine crops. Immature deciduous tree and vine crops use less water than mature crops. For tree and vine crops the peak K_c is reached when the canopy has reached about 70 percent ground cover. The program adjusts the mature K_c values (K_{cm}) as a function of percentage ground cover (C_g).
CUP also accounts for cover crop contribution to crop coefficient values for tree and vine crop. With a cover crop, the K_c values for deciduous trees and vines are higher. When a cover crop is present, 0.35 is added to the clean-cultivated K_c. However, the K_c value is not allowed to exceed 1.15 or to fall below 0.90.

-Input and Output: Daily mean weather data by month from CIMIS or from a non-CIMIS source can be used in CUP for the calculations of ET_o. Weather data include, solar radiation, maximum and minimum temperature, dew point temperature, wind speed, and rainfall. The program also allows for input of daily mean of ET_o or pan evaporation by month with monthly total rainfall data for estimating crop evapotranspiration. If pan data are input, then the program automatically estimates daily ET_o rates using a fetch value (i.e. upwind distance of grass around the pan) without the need for wind speed and relative humidity data. If daily mean temperature data by month are input, then CUP will use the Hargreaves-Samani equation to calculate ET_o. To run the application program to determine ET_c for a crop, it is also required to enter the crop information. The input data include as following:

- Crop name
- Planting date
- Ending date
- Initial growth wetting frequency
- Ground cover percentage on date B, C, D, and E, which are used to account for immaturity effect on K_c values for tree and vine crops.
- Cover crop dates

Outputs by CUP include as following:

- One year of daily weather data including calculated ET_o from weather data
- One year of daily calculated crop coefficients and crop evapotranspiration by crop for the current crop information
- Monthly total values of rainfall, ET_o and ET_c for the current weather and crop information
- Seasonal and annual total of ET_o and ET_c by crop, and a bar graph of monthly total of ET_o and ET_c by crop.

Data Management: It allows easy input of weather, ET_o, pan evaporation, and crop data for calculating crop evapotranpiration. It contains a table of monthly mean ET_o rates (in/day) by ET_o zone as a database from the California ET_o zones map for easy input. CUP comes with the "California Climate Data" program to provide monthly mean weather and ET_o data by day averaged over the period of record from CIMIS to input into the CUP program. CUP gives the user the opportunity to view the output values as they are created. In the CUP model, all weather and ET_o data are input as monthly mean data by day. There are 5 possible ways to input weather data into the CUP program. After data entry, the program allows us to write the current crop information and calculated crop coefficient, ET_o, and ET_c data to one row in the summary sheets of K_c, ET_o, and ET_c.

Software: The CUP model is an EXCEL program, which has been developed to provide a new tool for estimating crop evapotranspiration. CUP software is designed to input 5 different weather input data into the program to easily make evapotranspiration calculations for crops without changing the model code. CUP runs on IBM PC compatible Pentium-equivalent or higher, 16MB RAM, Windows 95/98, NT 4.0, Windows 2000, Windows XP. It is available to the public on CD's. A help file for the program is being written to explain the various components of the program and help users how to use the program to determine ET_c. In additions; it gives examples of input data format.